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Illustrating Harvest Effects on Site Microclimate in a High-Elevation Forest Stand

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Abstract

Three-dimensional contour surfaces were drawn for physiologically active radiation (PAR) and air and soil temperatures from measurements taken at a high-elevation site (1450 m) near the crest of the Cascade Range in central Washington. Measurements in a clearcut were compared with measurements from an adjacent uncut stand. Data for 31 days in July and August 1985 illustrated the rapid changes as storms off the Pacific Ocean displaced the dominant high pressure of summer.

Keywords: Physiologically active radiation, temperature, high-elevation forests, Washington.

Introduction

As part of a new program at the Forestry Sciences Laboratory in Wenatchee, Washington, a series of ecological, meteorological, and physiological studies have been started to determine the effects of logging and residue treatments on regeneration, secondary succession, and site productivity in high-elevation forest stands. Understanding how the environment changes as different treatments are applied is an important aspect of this work.

Microclimatic variables are being measured at several pairs of harvested and unharvested high-elevation sites in the Cascade Range of central Washington. This preliminary report uses data from one paired site to illustrate an analytical technique that presents an easily visualized summary of energy input and thermal response by air and soil. The data used in this paper clearly reflect the pronounced difference in microclimate of this clearcut and the adjacent uncut forest.

Weather conditions in the Pacific Northwest during summer are generally clear, dry, and warm to hot. Weather at this site showed little day-to-day variability for several weeks before the period described here. These 31 days were selected to show how rapidly weather can change in this forest zone as fringes of traveling storms penetrate into the dominant high pressure of summer. Several weeks of more seasonal conditions were again observed after this period.

PNW FOREST AND RANGE
EXPERIMENT STATION

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The Study

The site is about 1450 m in elevation and 8 km from the crest of the Cascade Range in the Little Wenatchee River drainage. Leavenworth, Washington, is about 50 km to the southeast. Aspect is southwest, and slopes are steep at 50 to 100 percent. Longspan high-lead logging was completed in 1983, residues were broadcast burned in 1984, and instruments were installed in late 1984. The clearcut is about 8 ha. Tree cover was old-growth mixed conifer with Pacific silver fir (*Abies amabilis* Dougl. ex Forbes), subalpine fir (*A. lasiocarpa* [Hook.] Nutt.), mountain hemlock (*Tsuga mertensiana* [Bong.] Carr.), and Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) predominating. Tree heights of dominants and codominants in the uncut forest are 20 to 30 m. Understory vegetation was sparse but responded vigorously after canopy removal. Rapidly developing seral shrubs can limit establishment and growth of tree seedlings and are an important management problem.

Hourly records were taken with instruments placed in the clearcut and in the adjacent uncut forest. Air temperature was measured in the clearcut and adjacent uncut forest at 1.3 m and 0.3 m above ground; soil temperature and soil moisture were measured at 0.035 m and 0.25 m below ground. All-wavelength solar radiation and humidity were measured only in the clearcut. Physiologically active radiation¹ (PAR) was measured at both locations and was an integral value for the hourly period.

Environmental records were taken each hour with a magnetic tape recorder. Tapes were collected periodically, read into a Data General MV 8000 computer,² and converted and scaled to provide a daily summary of the hourly measurements. Data were also transmitted to a mainframe computer at the University of Washington in Seattle for statistical analysis and graphic output.

From the various graphics programs available, we selected Template developed by Megatek Corp. It is versatile but not especially "user-friendly." A variety of viewpoints, scales, and axis rotations of the three-dimensional plots are possible. We selected a plot with a visually acceptable surface by using routines that deleted hidden lines and showed only the upper surface of the plot. Shading or vertical lines were added from the contour surface to the X- and Y-axes to enhance the figure's depth. Projection of the figures was orthographic. Contour intervals were set at 0.25 Einstein per square meter per hour for PAR, 1 °C for temperature, and 5 percent for relative humidity.

Results and Discussion

For each of the 744 data points (31 days, 24 data points per day) on the X- and Y-axes, a value was available for Z. Values of Z were the environmental measurements. Only PAR, humidity, and temperature relations are shown in this paper.

¹ Physiologically active radiation (PAR) is that radiation within the bandwidth of 400 to 700 nm required for assimilation and plant growth and development.

² The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others that may be suitable.

Figures 1A, 2A, 3A, 4A, 5A, and 6 are from the clearcut; figures 1B, 2B, 3B, 4B, and 5B are from the uncut forest. PAR measurements in figure 1, A and B, show that the canopy (canopy density of 81 percent) attenuated incoming radiation by 95 percent or more on an hourly basis. The irregular canopy contributed to the variation shown in figure 1B. Minimum canopy effect is at 1100 to 1200 hours and again near 1400 hours. The plot from the clearcut shows the effect on incoming radiation as storm clouds passed through the area. Humidity measurements also documented the passage of the moist Pacific air. In figure 6, humidity levels are high—80 to 90 percent during the moist, cloudy days—as compared with the 20 to 40 percent midday humidities at the beginning and end of the period.

Temperature at the soil-air interface was not measured in this study; however, at 0.035 m in the clearcut soil, temperatures as high as 36.2 °C were recorded (fig. 4A). Air temperature at 0.3 m was 29.7 °C (fig. 3A). The actual interface temperature was above these values though; earlier work (Fowler 1974, Geiger 1965, Helvey and others 1976, Hungerford 1980) indicates that temperatures as high as 50 to 70 °C can occur at the soil surface in dry, poorly consolidated materials with high solar-energy absorption. Greenhouse experiments with seedlings of several high-elevation east-side conifer species showed that 20 °C was near the optimum temperature for root growth of all species.³ No growth at all occurred in true firs at 30 °C, some growth occurred in Douglas-fir, and considerable root growth was observed in pine seedlings. (Copy continues on page 9.)

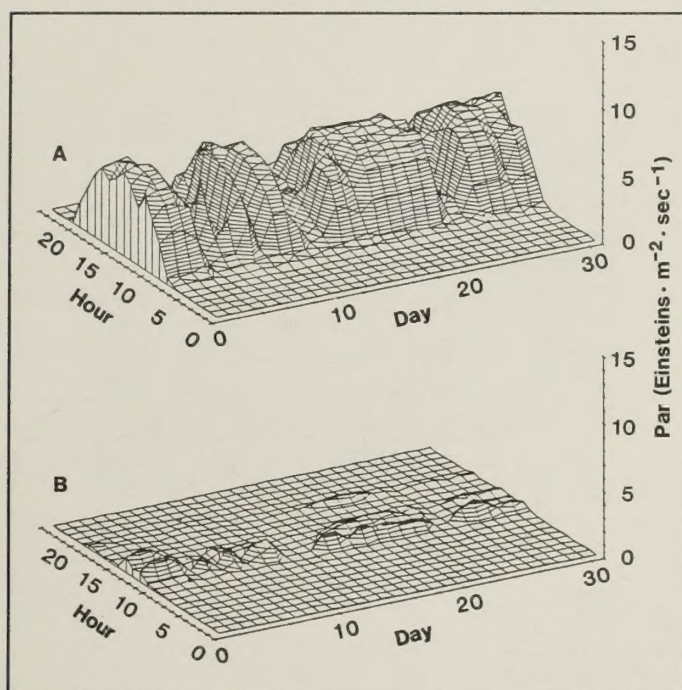


Figure 1—Physiologically active radiation (PAR), July 27, 1985 (day 0), to August 26, 1985 (day 31): A, in clearcut; B, in uncut forest.

³ Personal communication, W. Lopushinsky, Forestry Sciences Laboratory, Wenatchee, WA 98801.

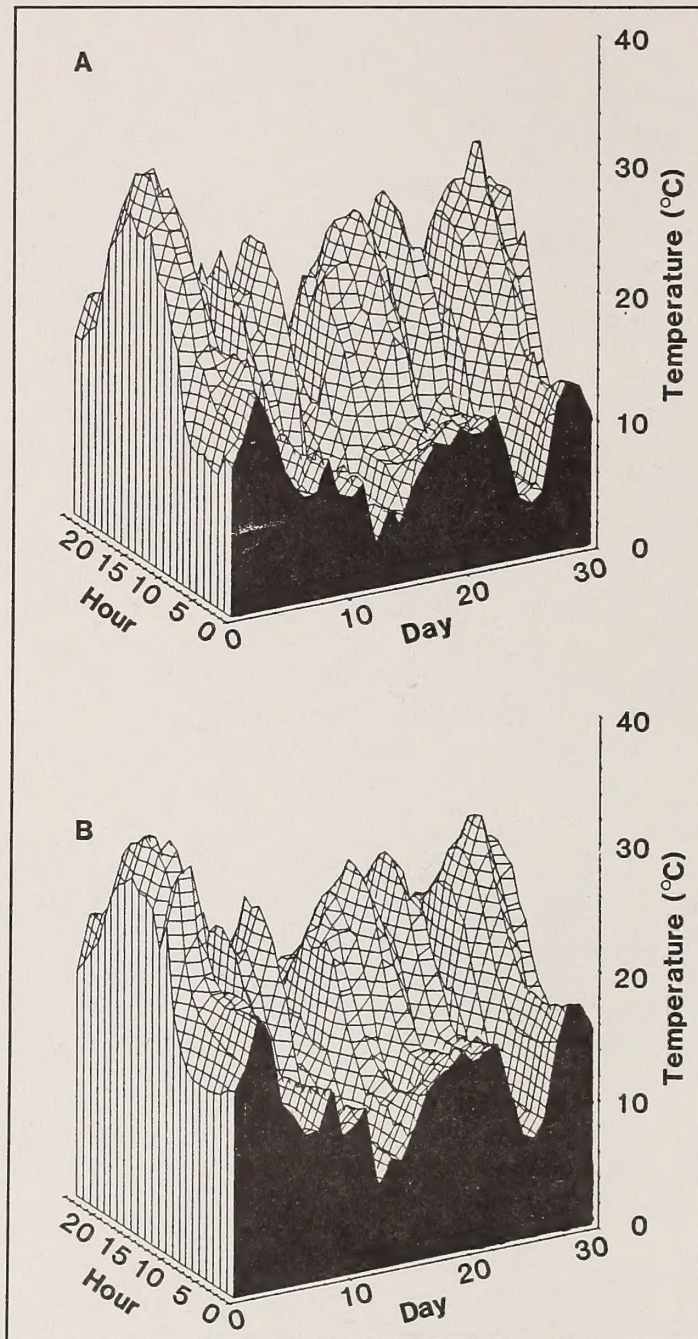


Figure 2—Air temperature at 1.3 m, July 27, 1985 (day 0), to August 26, 1985 (day 31): A, in clearcut; B, in uncut forest.

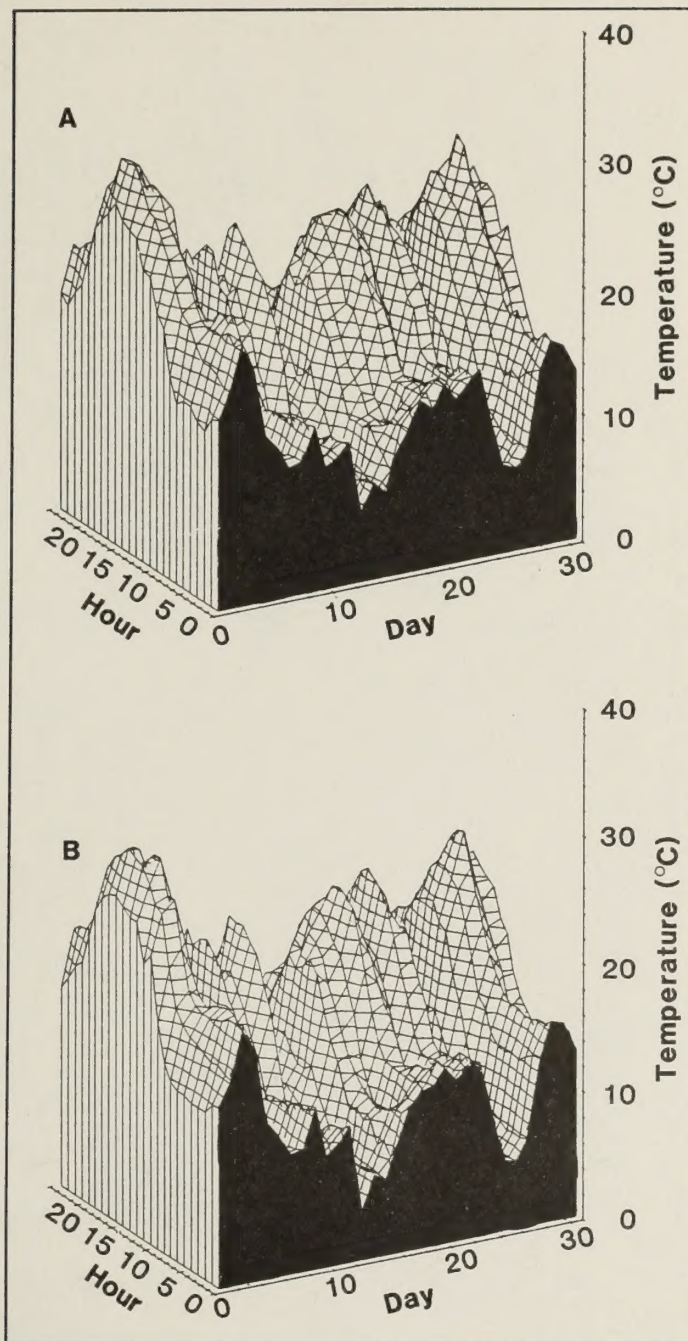


Figure 3—Air temperature at 0.3 m, July 27, 1985 (day 0), to August 26, 1985 (day 31): A, in clearcut; B, in uncut forest.

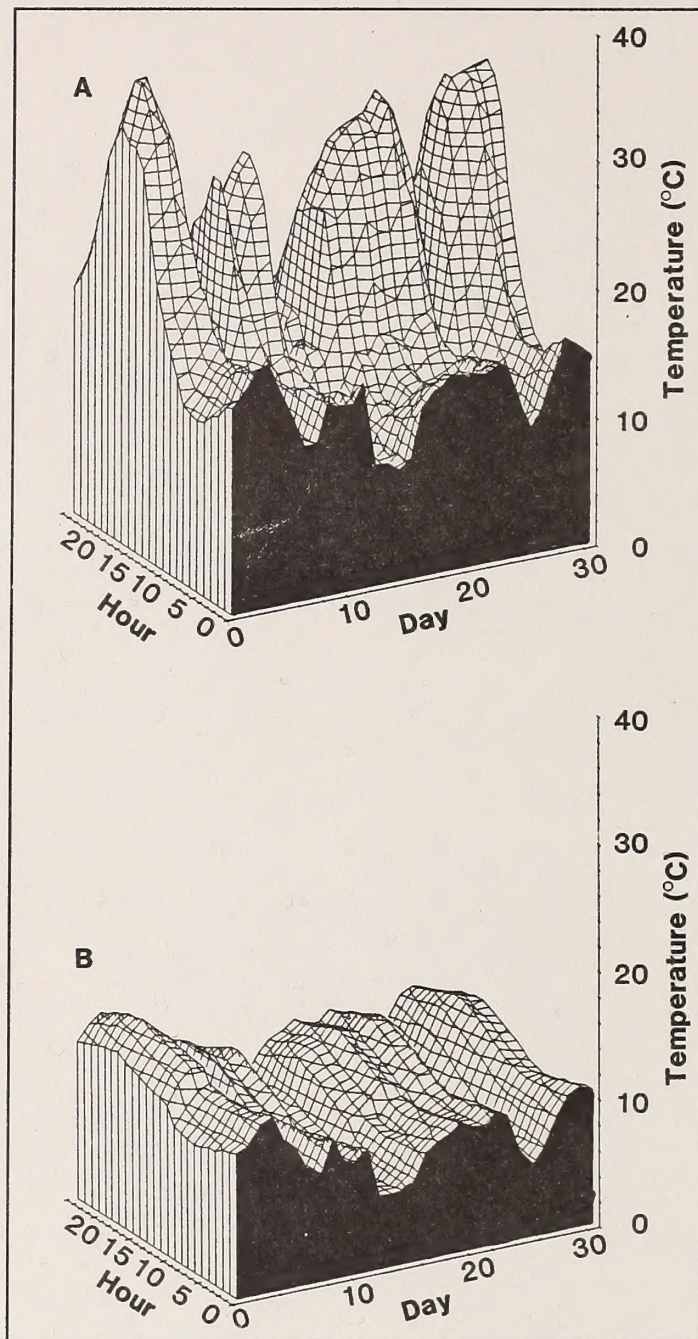


Figure 4—Soil temperature at 0.035 m, July 27, 1985 (day 0), to August 26, 1985 (day 31): A, in clearcut; B, in uncut forest.

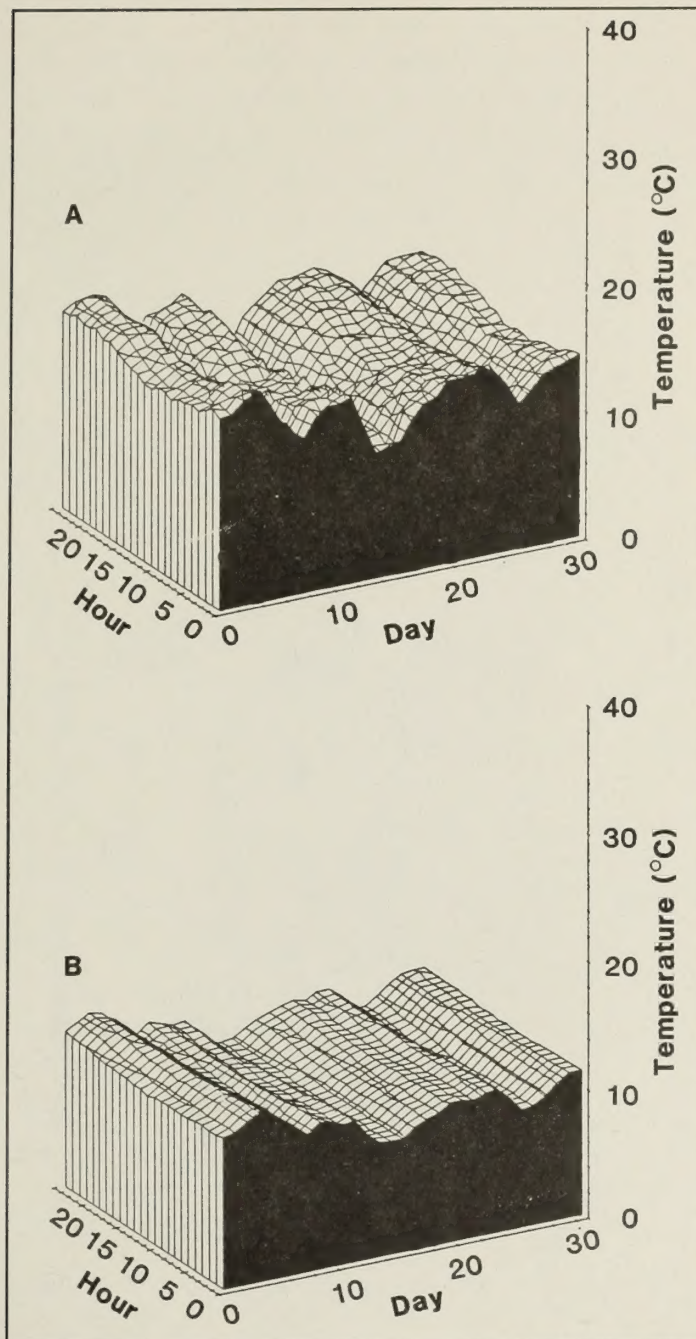


Figure 5—Soil temperature at 0.25 m, July 27, 1985 (day 0), to August 26, 1985 (day 31): A, in clearcut; B, in uncut forest.

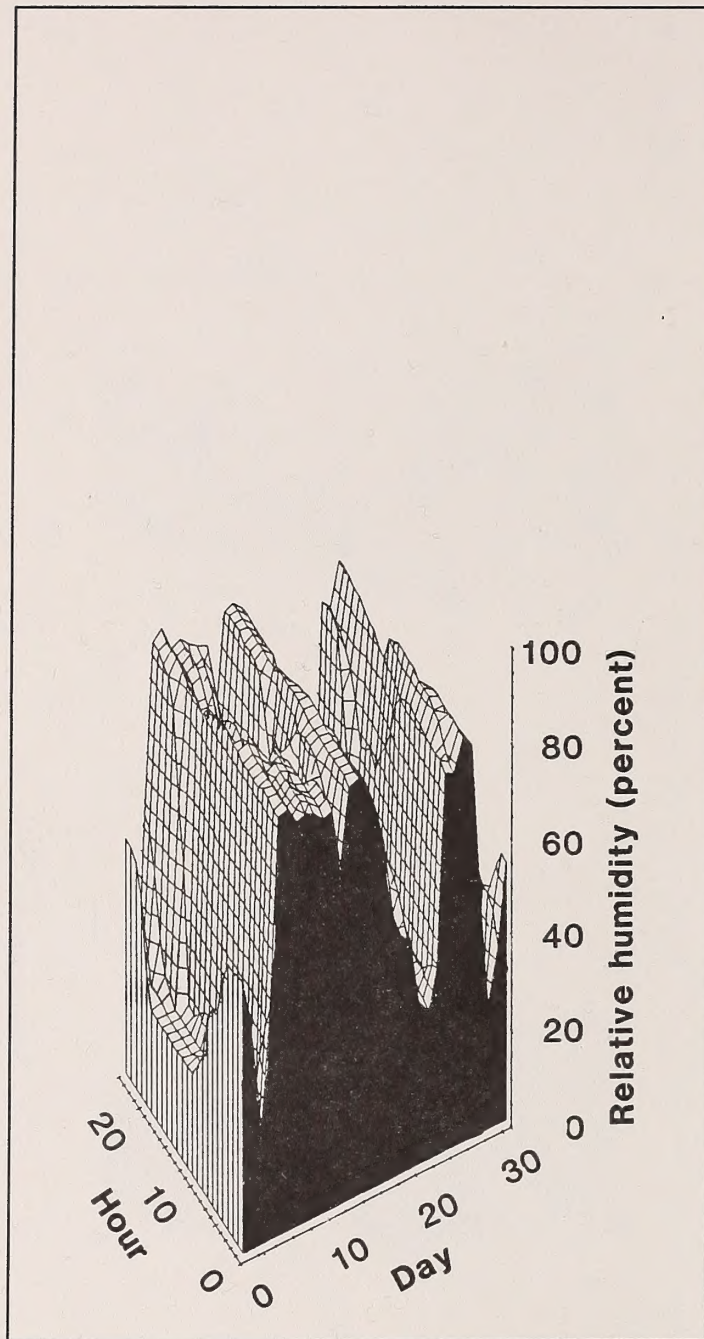


Figure 6—Relative humidity, July 27, 1985 (day 0), to August 26, 1985 (day 31) in clearcut.

The soil-air interface in the clearcut is the energy transforming surface—energy is received from the sun and dissipated by conduction, convection, evaporation, and reradiation. Distance from the surface decreases the amplitude of the diurnal temperature wave; air temperature at 0.3 m followed the soil temperature more closely than did air temperature at 1.3 m (fig. 2A). The soil temperature at 0.25 m often lagged behind the soil temperature at 0.035 m by several hours and showed a much reduced diurnal fluctuation (fig. 5A).

A tabulation of average hourly temperatures shows the zone of maximum heating (-*****-) for both the clearcut and the uncut forest:

<u>Location</u>	<u>Measurement height</u> (m)	<u>Average temperature</u> (°C)
Clearcut	1.3 air	12.7
	0.3 air	14.5
	0.035 soil	-*****- 17.2
	0.25 soil	13.0
Forest	1.3 air	15.7
	0.3 air	-*****- 13.6
	0.035 soil	9.5
	0.25 soil	10.6

In the clearcut, maximum heating took place at the soil-air interface; temperatures decreased further from the surface. In the forest, heating took place throughout the plant volume, and the maximum average temperature appeared to be between 0.3 m and 1.3 m.

Conclusions

A three-dimensional graphics program can be used to visually interpret interrelations between temperature patterns and incoming energy. The thermal difference between clearcut and uncut forest arose from the reduction in solar energy and the differing height of the zone of maximum heating. The maximum average temperature difference between soil in clearcut and uncut forest areas was 7.7 °C at 0.035 m for the 31 days. The forested site was less responsive in its temperature changes. During this time in late July and early August, all environmental measurements changed substantially as weather conditions changed with passing storms.

We did not monitor in detail growth and survival of outplanted seedlings at this location. Seedlings planted in fall 1984 after residue treatment fared poorly—the site was replanted in 1985. We suspect that extremes in temperature contributed to poor survival.

Graphics programs have other uses besides presenting an overview of site interactions. The programs can display time-temperature relations, such as degree hours above a threshold temperature, by selecting a lower limit for the contour bands.

Displaying periods with potentially debilitating conditions—soil moisture or temperature beyond the tolerance limits of the plants—requires only a selection of the appropriate contour limits. Programs of this complexity are being developed by several vendors for personal computers.

English Equivalents

<u>To convert</u>	<u>Into:</u>	<u>Multiply by:</u>
Meters (m)	feet	3.282
Kilometers (km)	miles	0.6214
Celsius (°C)	Fahrenheit	$(9/5 \text{ } ^\circ\text{C}) + 32$
Hectares (ha)	acres	2.471
Nanometers (nm)	inches	1×10^9

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